Subwavelength metamaterials: from on-chip devices to free-space beams

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Silicon-on-insulator is rapidly becoming the optical integration platform of choice for applications ranging from telecom and datacom to sensing and quantum photonics. Silicon waveguides exhibit a strong index contrast, and can be produced via mature CMOS processeses with high-resolution lithography, enabling dense optical integration. However, few materials are compatible with these processes, severely limiting the degrees of freedom for device design. Subwavelength structures overcome this limitation by enabling metamaterials with adjustable optical properties: their subwavelength periodicity suppresses diffraction, allowing light to travel through them as it would in an equivalent homogeneous yet anisotropic material [1]. These properties have been extensively exploited to create low-loss devices with very broad bandwidths and compact footprints [1].

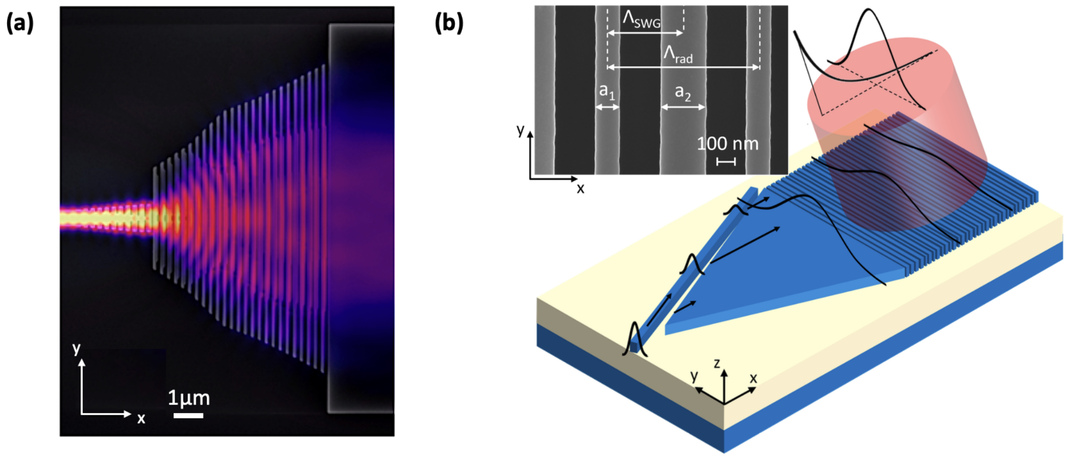

Fig. 1 (a) Scanning electron micrograph of a metamaterial-based spotsize converter capable of on-chip beam expansion by a factor $\times 24$ over a length of only 7 µm. The simulated electromagnetic field is superimposed. (b) Our optical antenna generates an off-chip with beam with a mode field diamater of 350 μm, corresponding to a 6 cm Rayleigh distance. The inset shows a scanning electron micro-graph of the double subwavelength structure that enables weak radiation strengths with a full etch step.

In this invited talk we review some of our latest advances in the field of subwavelength metamaterials. We will discuss prism-assisted, subwavelength structured fiber-to-chip couplers that achieve an unprecedented coupling efficiency of 0.2 dB by exploiting the single-beam diffraction regime, and which are useful in quantum photonics applications where ultra-low losses are of critical importance [2]. Furthermore, we present a novel inverse design approach, based on dividing the device into a small number of cells, each containing a different metamaterial [3]. The comparatively small number of parameters results in straightforward optimization process and yields a device similar to a graded-index lens, as shown in Fig. 1(a). A $\times 24$ on-chip expansion is achieved over a length of only 7 µm, yet covering a bandwidth exceeding 150 nm. Finally, we discuss a novel optical antenna, shown in Fig. 1(b), which radiates a nearly diffraction-less beam, with a record 350 µm mode field diameter, into freespace, thereby enabling interaction with targets situated at centimeter-scale distances from the chip [4].

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References

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